Extraction Losses from the Main Injector

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An interesting situation has been reached regarding extraction losses from the Main Injector. Having achieved a step size of 14 mm we have reached a local minimum of around .5% that is actually difficult to significantly improve without a high beta insertion. This quasi minimum results from some numerical coincidences relating the current state of the art in septum design and the relatively low momentum of the Main Injector extracted beam. The concept is straightforward; the momentum is low enough that the effective length of the septum is so short that not all protons that hit the septum wires interact.

Figure 1 is a schematic of the extraction process. The absorbtion length of tungsten is 10.3 cm, and together with the packing fraction of .02 for the wires, yields 515 cm as the effective absorbtion length λ. (The wires are actually made of a Tungsten-Rhenium alloy whose absorbtion length will be slightly longer so that it is conservative to use W in the calculation.) The wires start to break at 120 kV and hence we will assume a high voltage of 100 kV on the wires.

The purpose of the electrostatic septum is to give a separation between the extracted beam and the circulating beam at the position of the magnetic septum. This separation is proportional to the square root of the product of the beta function at the septa locations times the angular kick given by the electrostatic septum,

$$\Delta X \sim \sqrt{\beta_{ES}\, \beta_{MS}}\ \Theta$$

The extraction inefficiency is a function of the effective wire size divided by the step size S. For a short septum of the type that we are discussing here, it is possible to constuct and align the septum so that the effective

In the case where the gap is given by $f\,S$, we can see that around our situation where l/τ is around 1/2 that there is no variation of inefficiency with step size; and with the gap given by $f+S$ we see that the inefficiency does decrease with an increasing step size but certainly not as fast a linearly.

Hence we are in the situation where increasing the step size does not help as much as one would think. The beneficial effect of a high beta insertion then is not to increase the step size but to reduce the length of the septum. If we go back to our expression for the inefficiency and to our expression for the separation of the beams at the magnetic septum,

$$\varepsilon = \frac{2d}{S}\left[1 - e^{-\ell/\tau}\right] \sim \frac{2d\ell}{S\tau} \qquad \Delta X = \sqrt{\beta_{ES}\beta_{MS}}\,\theta \sim \sqrt{\beta_{ES}\beta_{MS}}\,\frac{V\ell}{gp}$$

and we note that theta is directly proportional to l,then it is apparent that increasing beta at both septa will linearly decrease the losses while keeeping the desired separation the magnetic septum.

The situation is still slightly better since the particles intersecting the wire plane experience some net field and will move out before interacting. Hence we believe that the extraction inefficiency with a 14 mm step size will be less than .5% and could approach .35% due to the partial electric field effect.